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CULL AND BREAKAGE FACTORS AND OTHER TREE MEASUREMENT TABLES FOR REDWOOD

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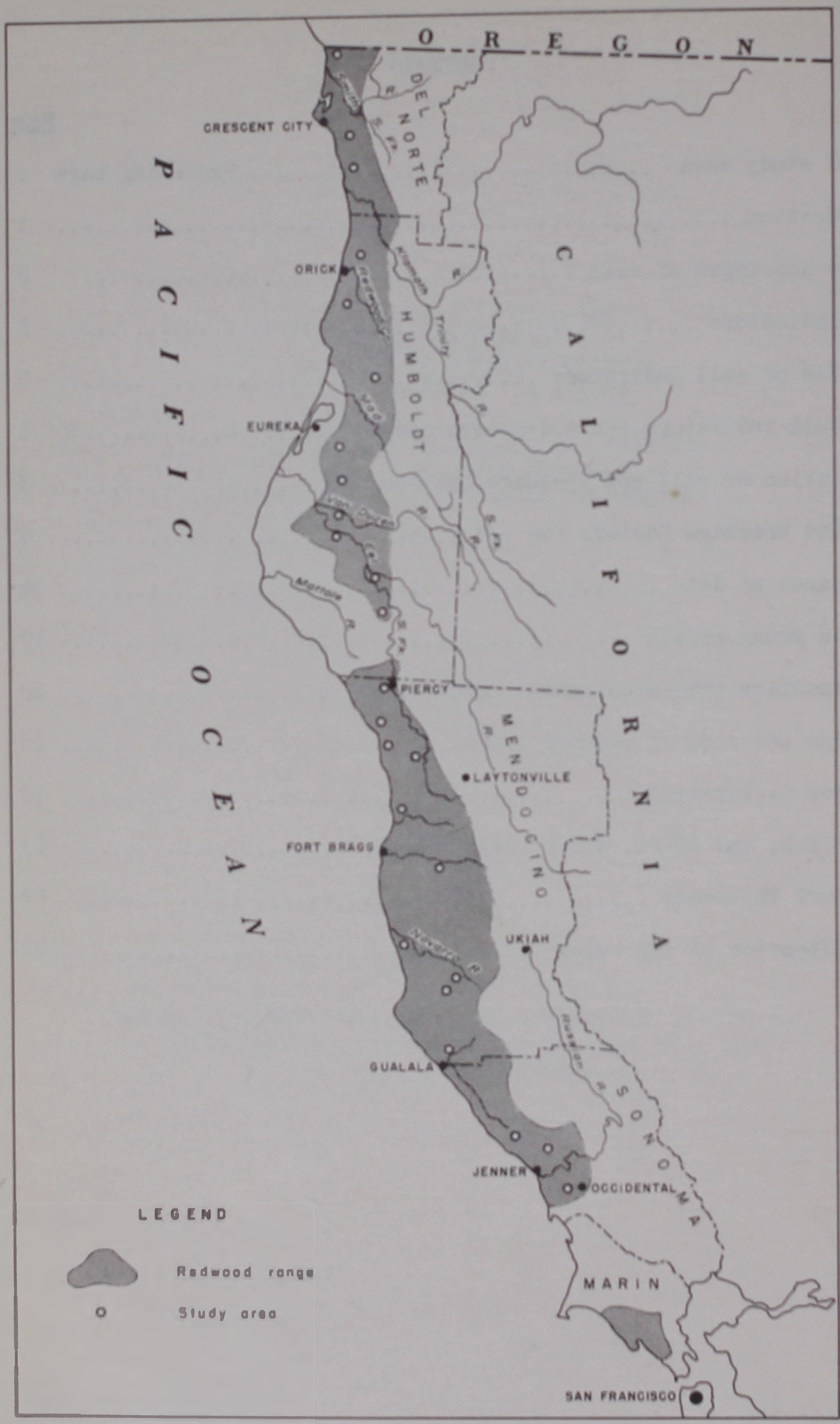
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HUMBOLDT
EUREKA
TRINITY
MENDOCINO
LAYTONVILLE
PIERCY
FORT BRAGG
UKIAH
GUALALA
SONOMA
JENNER
OCCIDENTAL
MARIN
SAN FRANCISCO
PACIFIC OCEAN
CALIFORNIA
LEGEND
Redwood range
Study area

CULL AND BREAKAGE FACTORS AND OTHER TREE MEASUREMENT TABLES FOR REDWOOD

By
James W. Kimmey and E. M. Hornibrook[1/]

INTRODUCTION

Cull is that part of a living tree which is not merchantable because of defect. Any additional loss of merchantability because of cracks, splits, and shattering due to felling and bucking is termed breakage. Cull and breakage are closely related and frequently inseparable. When cull in a standing tree is expressed as percentage of its gross volume, the percentage is termed the cull factor. After the tree is felled, the additional loss due to breakage, when expressed as a percentage of the gross volume, is termed the breakage factor. The breakage factor is directly additive to the cull factor; the sum of the two is the factor for total loss.

The cull and breakage discount factors given here were used in compiling net volume and growth of redwood, Sequoia sempervirens (D. Don) Endl., as part of the Forest Survey in California. The results are published in anticipation that they may be useful to other workers in the redwood forests. Cull factors for other forest tree species in northwestern California have been published.[2/]

The studies in redwood were conducted jointly by the Division of Forest Pathology, Bureau of Plant Industry, Soils and Agricultural Engineering, and the Division of Forest Economics, California Forest and Range Experiment Station, with the cooperation of timber operators throughout the redwood region.

Cull and breakage values for both old-growth and young-growth redwood are presented. Data on old growth are from 25 sample study areas distributed throughout the redwood region, as indicated on the accompanying map, and data on young growth are from two sample study areas in Mendocino County.

1/ Respectively, Pathologist, Division of Forest Pathology, Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture, 720 Appraisers Building, San Francisco 11, California; and Forester, California Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture, P.O. Box 245, Berkeley 1, California. Paul C. Lightle, of the Division of Forest Pathology, contributed valuable assistance in the field work and compilation of data.

2/ Kimmey, James W. Cull factors for forest-tree species in northwestern California. California Forest and Range Experiment Station, Forest Survey Release No. 7. 30 pp. illus. 1950.

Two types of cull factors are presented. Either type may be used, but the two should not be used together. One type, based on the total cull in a tree, regardless of source, is called a "flat factor." The other, based on cull found in association with specific indicators such as fire scars or broken-out tops, is termed an "indicator factor." The flat factors are for use with gross cruise values of extensive areas, or when cull indicators are not recorded. Since they are based on range-wide averages, the flat factors cannot be expected to apply as accurately to limited areas as will the indicator factors.

For old-growth redwood, flat factors by 10-inch d.b.h. classes are given separately for the southern portion (Sonoma and Mendocino Counties) and the northern portion (Humboldt and Del Norte Counties) of the redwood region. Indicator factors are given by 10-inch d.b.h. classes for the entire redwood region.

Only one type of breakage factor, a flat type applicable to the entire redwood region, is given. The breakage factors are expressed by 10-inch diameter classes and they are directly additive to either the corresponding flat cull factors or the applicable indicator factors.

This report also includes some supplementary tree-measurement data, not commonly available for redwood, which have proved useful in the Forest Survey.

CAUSES AND TYPES OF CULL

Cull in standing old-growth redwood is largely due to rot. Sound defect attributable to such causes as crook, sweep, and excessive knottiness or limbiness is negligible. Shake or rift-crack is the only sound defect that contributes appreciably to the cull. This type of defect was disregarded, however, in computations of cull for cubic volumes.

Although the primary cause of cull was rot, there was some board-foot volume loss attributable to burning, for example, in gooseperns and large fire scars (Table 1). Some loss also resulted from broken-out tops, but this was included with cull from rot because most breaks in tops result from decay.

Both of the two basic types of decay, "white rot" and "brown rot," are found in redwood. Heart rots of the brown-rot type, chiefly from the fungus Poria sequoia Bonar, predominate in the southern part of the tree's range; those of the white-rot type, caused chiefly by the fungus Poria albipellucida Baxter, predominate in the northern part of the range (Tables 2 and 3). In this tree species, wood in the advanced or late stage of decay, in both the white rots and brown rots, is characteristically accompanied by a considerable amount of wood in the incipient or early stage of decay. Wood in this stage of decay is generally called "black heart" by the lumber trade and does not yield usable

lumber after seasoning. A relatively high percentage of cull was for incipient decay in this study. The percentage of rot that was of the white-rot type increased from 1 percent in Sonoma, the southernmost county, to 4 percent in Mendocino, 24 percent in Humboldt, and 55 percent in Del Norte, the northernmost county.

Cull due to cubic-foot volume loss from broken-out tops and from fire, though relatively small, is shown separately in table 2.

Table 1.- The relative importance of the three principal causes of cull in board-foot volume from the stump to a 12-inch top in old-growth redwood--by counties

County	Percent of gross volume				Percent of total cull caused by--		
	Culled by--			Net			
	Rot	Shake	Fire		Rot	Shake	Fire
Sonoma	30.6	2.2	1.5	65.7	89.1	6.5	4.4
Mendocino	27.2	1.8	2.2	68.8	87.1	5.7	7.2
Humboldt	32.4	2.1	0.8	64.7	91.8	6.0	2.1
Del Norte	45.2	1.1	1.2	52.6	95.2	2.3	2.5
All	33.9	1.8	1.3	63.0	91.6	4.8	3.5

Table 2.- Cull percentages in the gross cubic-foot volume of old-growth redwood, from the stump to a 4-inch top, by causes, types of rot, and stages of decay, in each county of the main commercial range

County	Brown rot		White rot		Fire	Broken tops	Total cull
	Incipient stage	Advanced stage	Incipient stage	Advanced stage			
Sonoma	6.7	10.8	T1/	0.1	0.9	0.3	18.8
Mendocino	8.1	8.8	0.2	0.4	1.4	0.9	19.8
Humboldt	6.6	9.5	1.8	3.1	0.6	1.9	23.5
Del Norte	4.9	8.7	3.9	12.8	0.8	2.7	33.8
All	6.6	9.2	1.8	4.4	0.9	1.7	24.6

1/ Trace, less than 0.05 percent.

Table 3.- Percent of total cubic-foot cull in old-growth redwood caused by brown rot, white rot, fire, and broken tops, in each county of the main commercial range

County	Brown rot		White rot		Fire	Broken tops
	Incipient stage	Advanced stage	Incipient stage	Advanced stage		
Sonoma	35.7	57.3	0.2	0.8	4.6	1.4
Mendocino	41.0	44.6	1.1	2.0	6.9	4.4
Humboldt	27.9	40.2	7.9	13.4	2.4	8.2
Del Norte	14.4	25.8	11.6	37.9	2.3	8.0
All	26.9	37.3	7.2	18.1	3.5	7.0

CULL INDICATORS

The amount of cull may vary considerably in redwood trees within a given diameter class at different latitudes, or on different sites at any given latitude. In general, the cull factors were found to be progressively larger from the southern to the northern parts of the redwood range, and at a given latitude they became larger with increase in elevation. Accompanying these increases in cull are general increases in the frequency of cull indicators.

The following were found to be reliable indicators of significant amounts of cull:

1. Bole wound. Any bole wound, scar, or catface extending into the heartwood but not to its center. It may be at any location on the bole. It is frequently caused by fire. (Fig. 1).

2. Goosepen. A deep fire wound extending to or beyond the center of the heartwood and always at the base of the tree. (Fig.2).

3. Broken top. Any broken-out top regardless of location (Fig.3), or any large sucker-type branch regardless of location on the bole (Fig. 4). This does not include spike, or dead, tops that are not broken out (Fig. 5), or adventitious or epicormic branching caused by a recent source of additional side light to the trunk. The large sucker-type branches seem to be stimulated by extensive cull in the upper bole, which usually starts in a broken-out top. Often, other indications of the old broken top are not discernible from the ground.

Use of Cull Indicators

Trees having none of these three indicators should be classed as having no indicators. Spike or dead tops alone are not associated with appreciable percentages of cull; therefore, such trees should be considered as trees with no indicators. All cull that is not associated with recognized indicators is taken care of by the small cull factors for trees with no indicators. These factors become smaller as the trees become older, because cull indicators develop as the trees grow older. About 50 percent of the study trees below 71 inches d.b.h. had no recognized cull indicators; 12 percent over 100 inches d.b.h. had none. Only one study tree over 110 inches d.b.h., and none over 120 inches had no recognized cull indicators. Breakage factors for trees with no cull indicators are somewhat larger than for trees with indicators.

A single tree may have more than one cull indicator. However, except for bole wounds, the number of like indicators has no significance in applying cull factors. For example, five sucker branches would require the same cull factor as one sucker branch. The cull indicators may be considered of two general classes as to location: lower bole and upper bole.

Broken top or sucker shoots are always in the upper bole, and goosepen is always in the lower bole, while bole wound may be in either the upper or lower bole. When two indicators occur on a tree, their cull factors are additive only if one is in the upper bole and the other in the lower bole. A bole wound is disregarded when it occurs in the lower bole with a goosepen or in the upper bole with a broken top.

Thus, only four combinations of factors are possible in a tree:

1. Goosepen + broken top.

2. Broken top + bole wound in lower bole.

3. Goosepen + bole wound in upper bole.

4. Bole wound in lower bole + bole wound in upper bole.

Since there is often an overlapping of defect from broken top with that from lower indicators, cull factors have been worked out for combinations 1 and 2 and are included in the tables. In combination 3, the two cull factors are directly additive. In combination 4, the cull factor for bole wound is simply doubled.

Wide-crotched forks in the bole usually indicate an old broken top and should be so considered, while acutely angled forks usually do not indicate appreciable cull. Flat or dubbed-off tops in trees are not always caused by old broken-out tops. Such trees should not be regarded as having a broken top unless there is some other evidence, such as sucker-type branches, indicative of a broken top.

CULL INDICATORS FOR OLD GROWTH REDWOOD (opposite page)

Fig. 1.- Bole wound at the base of a tree, caused by fire.

Fig. 2.- Goosepen caused by repeated burning that has destroyed nearly all the heartwood to a height of more than 20 feet.

Fig. 3.- Broken top in a large old growth tree, left after logging because of excessive cull.

Fig. 4.- Large sucker type branch, indicating appreciable cull in the upper bole.

Fig. 5.- Dead top which is not an indicator of an appreciable amount of cull.

Fig. 1

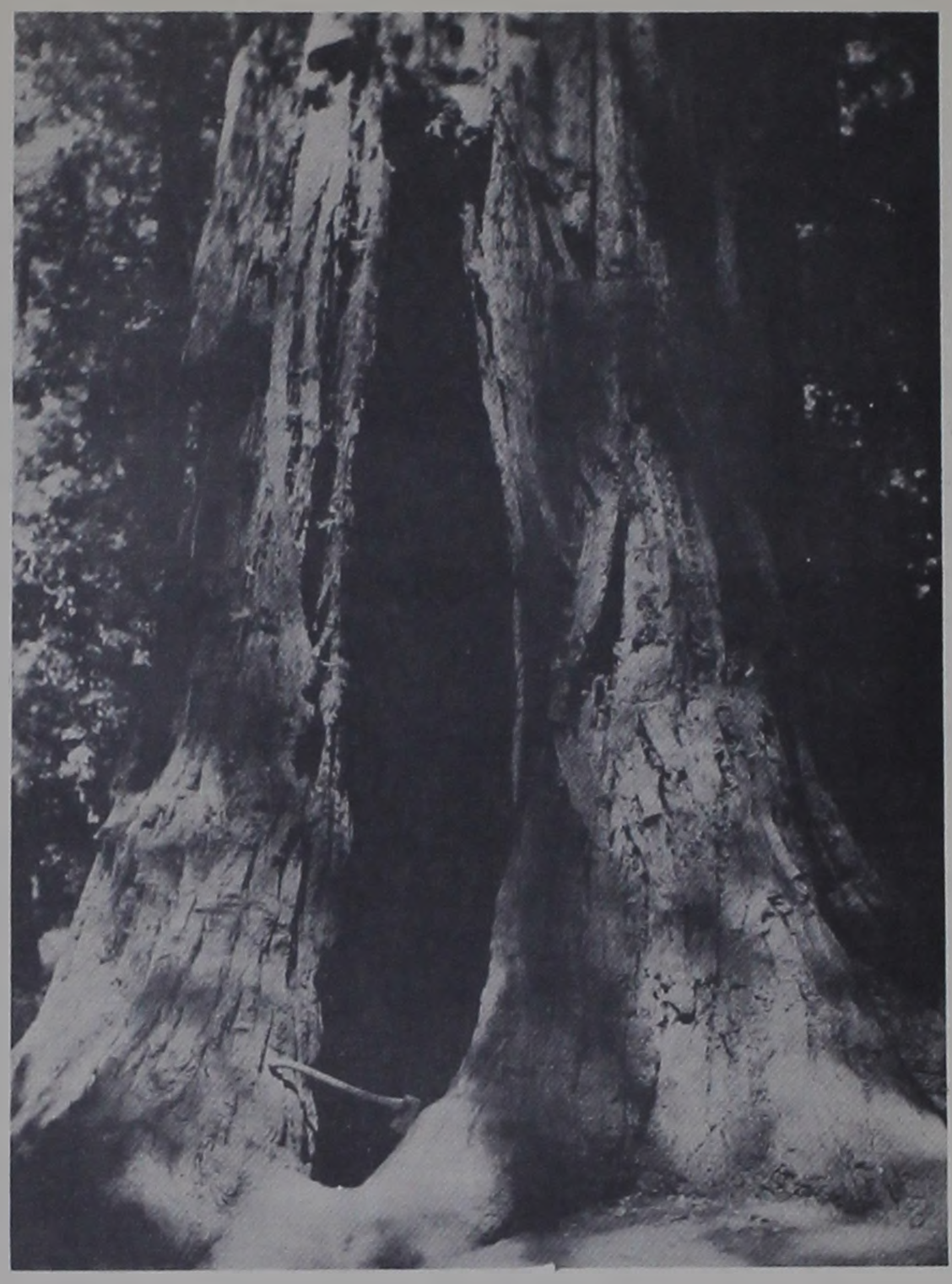

Fig. 2

Fig. 3

Fig. 4

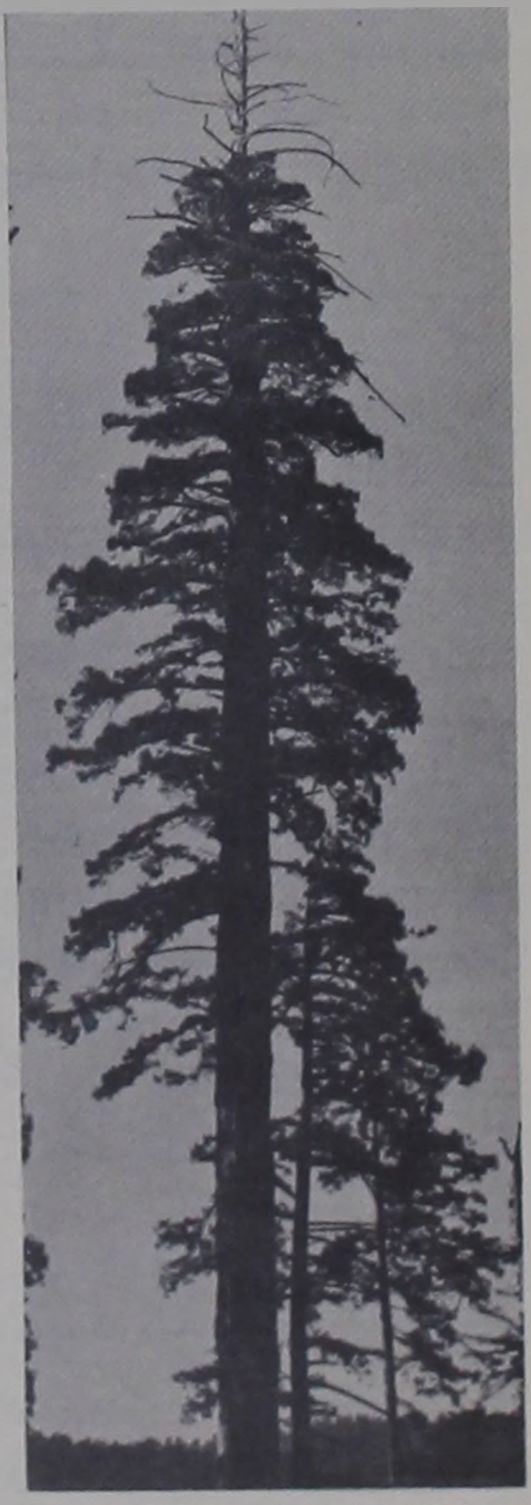

Fig. 5

APPLICATION OF CULL AND BREAKAGE FACTORS

The cull and breakage factors by d.b.h. classes are applicable to gross volumes as read from Hallin's volume tables,3/ and should be used in conjunction with them to determine net volumes. Like the figures in the volume tables, these factors are averages and should not be expected to give accurate estimates of net volume for individual trees. Since the amount of cull may vary on different sites and from locality to locality within the redwood range, the flat factors, which are derived from range-wide averages of cull, should not be expected to give accurate estimates for stands of limited area. The indicator factors, being derived from averages for individual indications of cull, will in general apply more accurately to smaller areas than the flat factors.

The factors applying to board-foot volumes are based on Scribner Decimal C log rule. Because of the similarity of this rule and the Spaulding log rule, and because the factors are expressed as percentages, these factors will apply generally to the Spaulding rule as well. These factors should not be used with the Humboldt log rule, however, because the Humboldt rule includes allowances for cull and breakage.

Any log that was more than 50 percent cull was considered all cull in board-foot computations, and any log that was more than 75 percent cull in cubic feet was considered all cull in cubic-foot computations. Any inconsistencies in the ratio of cubic to board-foot percentages may be accounted for in part by the fact that shake was regarded as a defect in making board-foot deductions but as not causing loss of cubic volume of wood; and in part to making no allowance in cubic-foot deductions for saw kerf, short lengths, and trimming.

All trees were scaled in 20.5-foot logs, starting from a 3-foot stump for trees up to 50 inches d.o.b. at 20 feet (diameter outside bark at 20 feet above the ground), and from a 3.5-foot stump for trees over 50 inches d.o.b. at 20 feet. Deductions for defects were made in accordance with the National Forest Scaling Handbook.

When the flat factors are to be used, cruisers should not tally trees that are obviously completely cull--that is, trees that would not be felled in a clear-cut operation. Such trees were not available for study, as none were felled on the logging operations sampled. Some trees used in the study were completely culled, but the extent of defect was not obvious in the standing trees.

In order to apply the indicator factors, the cruiser should be thoroughly familiar with the three general types of indicators and learn them by number. In cruising, he should examine each sample tree for cull indicators. If any indicators are present, they may be recorded by number parenthetically alongside the number of logs for each tree in the cruiser's

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3/ Hallin, William. Volume and taper tables for old-growth coastal redwood. Mimeographed. California Forest and Range Experiment Station, Berkeley, California. 1941.

tally. For example, a six-log tree with a goosepen would be tallied under the appropriate d.b.h. class, thus: 6(2). If this tree had, in addition to the goosepen, a fire-scar, sucker and broken top, it would be recorded as: 6(2+3)--the number 2 representing the goosepen and the number 3 the broken top. The fire-scar is disregarded because the goosepen has the larger basal factor, and the sucker is only a concurrent indicator of the cull from the broken top. The cull factor would be found in the table under the column headed "Goosepen + broken top" and numbered "2+3."

The cull factors for trees with no indicators should be applied to all trees in the cruiser's tally that do not have recognized cull indicators. Trees with only dead or spike tops or other indicators of minor amounts of cull should be treated as though they had no indicators.

The separate breakage factors given for trees that do not have cull indicators should be used for all trees without cull indicators.

CULL AND BREAKAGE FACTORS FOR OLD GROWTH

Cull and breakage factors given in tables 4 to 9, inclusive, were read from smoothed curves for 10-inch d.b.h. classes. If d.b.h. classes other than those given are desired, the values may be determined by interpolation, or by replotting the curves and reading off the intermediate values. The breakage factors given for redwood appear to be small. This is due to the fact that breakage which occurred in portions of a tree that were culled for other defect, such as rot or shake, was not included in the breakage factors.

The cull and breakage factors that apply to board-foot volumes are given for the bole from the stump to the actually utilized top. In 44 percent of the cases, this was to the first break; hence breakage factors for this section of the bole are relatively small. Factors are given also for board-foot volumes to a fixed 12-inch top diameter inside bark.

Cull and breakage factors that apply to cubic-foot volumes are given for the bole from the stump to the utilized top, and to a fixed 4-inch top diameter inside the bark. Factors for cubic volumes to a 12-inch top d.i.b. were also computed, but when these were rounded off to the nearest one percent they were practically identical to those to a 4-inch top; therefore, they have not been included here.

In table 4, flat factors are given for board-foot volumes, both to a utilized top and to a 12-inch top, for Sonoma and Mendocino Counties and for Humboldt and Del Norte Counties. In table 5, similar factors are given for cubic-foot volumes. Cull-indicator factors and breakage factors are given first for board-foot volumes, to a utilized top in table 6 and to a 12-inch top in table 7; then for cubic-foot volumes, to a utilized top in table 8 and to a 4-inch top in table 9. For total loss due to cull and breakage, the breakage factor should be added to the cull factor for each sample tree. Trees without cull indicators have different breakage factors than trees with cull indicators.

Table 4.- Flat factors1/ for gross board-foot volume

Percentage that is cull, and percentage lost through breakage, in old-growth redwood, by 10-inch d.b.h. classes--in the southern and northern portions of the redwood region.

D.b.h. class, inches	To utilized top			To 12-inch top		
	Cull		Break-age	Cull		Break-age
	Sonoma and Mendocino Counties	Humboldt and Del Norte Counties		Sonoma and Mendocino Counties	Humboldt and Del Norte Counties	
	Percent	Percent	Percent	Percent	Percent	Percent
21-30	20	--	0	18	--	2
31-40	20	12	1	19	6	4
41-50	21	13	1	21	10	6
51-60	21	14	2	23	14	7
61-70	22	16	2	25	19	7
71-80	23	19	2	28	24	7
81-90	25	23	3	31	29	7
91-100	28	27	3	35	35	6
101-110	31	32	3	39	42	5
111-120	34	38	2	44	49	4
121-130	39	45	2	50	56	3
131-140	--	52	2	--	63	3
141-150	--	60	2	--	71	2
151-160	--	69	2	--	79	2
161-170	--	78	2	--	87	2
Average	26	31	--	32	40	--

1/ Based on the average cull in a diameter class, regardless of cause or association with cull indicators.

Table 5.- Flat factors[1/] for gross cubic-foot volume

Percentage that is cull, and percentage lost through breakage, in old-growth redwood, by 10-inch d.b.h. classes--in the southern and northern portions of the redwood region

D.b.h. class, inches	To utilized top			To 4-inch top		
	Cull			Cull		
	Sonoma and Mendocino Counties	Humboldt and Del Norte Counties	Breakage	Sonoma and Mendocino Counties	Humboldt and Del Norte Counties	Breakage
	Percent	Percent	Percent	Percent	Percent	Percent
21-30	10	--	0	9	--	2
31-40	10	4	0	11	4	5
41-50	10	6	1	12	6	6
51-60	11	8	2	14	9	7
61-70	11	10	2	16	12	7
71-80	12	12	2	18	16	7
81-90	13	14	3	21	20	7
91-100	14	16	3	24	24	6
101-110	16	19	3	28	28	5
111-120	18	22	2	34	33	4
121-130	21	25	2	40	38	3
131-140	--	29	2	--	43	3
141-150	--	33	2	--	49	2
151-160	--	38	2	--	57	2
161-170	--	44	2	--	66	2
Average	13	18	--	20	27	--

1/ Based on the average cull in a diameter class, regardless of cause or association with cull indicators.

Table 6.- Indicator factors[1/] for gross board-foot volume to a utilized top

Cull and breakage in trees without, and in trees with, cull indicators in old-growth redwood--by 10-inch d.b.h. classes

D.b.h. class, inches	Trees with no indicators		Trees with indicators					
			Cull associated with--					
	Cull	Breakage	Bole wound (1)	Goosepen (2)	Broken top (3)	Bole wound + broken top (1 + 3)	Goosepen + broken top (2 + 3)	Breakage
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
21-30	15	0	16	21	16	38	41	0
31-40	10	1	16	25	16	38	45	1
41-50	7	1	17	29	16	39	49	1
51-60	5	2	17	34	16	39	53	2
61-70	3	3	18	39	16	40	58	2
71-80	2	3	19	44	17	42	63	2
81-90	2	4	20	49	18	44	69	2
91-100	2	5	22	55	19	46	76	2
101-110	1	5	25	62	21	50	84	2
111-120	1	6	28	70	23	55	94	2
121-130	1	7	32	79	26	61	100	2
131-140	1	7	36	90	30	67	100	2
141-150	1	8	40	100	35	75	100	2
151-160	1	9	45	100	41	83	100	2

1/ Based on the average cull associated with specific cull indicators.

Table 7.- Indicator factors1/ for gross board-foot volume to a 12-inch top

Cull and breakage in trees without, and in trees with, cull indicators in old-growth redwood--by 10-inch d.b.h. classes

D.b.h. class, inches	Trees with no indicators		Trees with indicators					
			Cull associated with--					
	Cull	Breakage	Bole wound (1)	Goosepen (2)	Broken top (3)	Bole wound + broken top (1 + 3)	Goosepen + broken top (2 + 3)	Breakage
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
21-30	13	2	14	19	24	45	45	2
31-40	9	4	14	21	25	46	48	4
41-50	7	6	15	24	25	47	51	5
51-60	5	8	15	27	26	48	54	5
61-70	4	9	16	30	27	49	58	5
71-80	4	10	17	34	28	51	63	5
81-90	3	11	18	38	30	54	69	5
91-100	3	11	20	42	32	57	75	4
101-110	3	12	22	47	35	61	83	4
111-120	3	12	25	52	38	66	91	4
121-130	3	12	29	58	41	72	100	3
131-140	3	12	33	64	45	78	100	3
141-150	3	12	38	71	50	84	100	2
151-160	3	12	44	80	56	90	100	2

1/ Based on the average cull associated with specific cull indicators.

Table 8.- Indicator factors1/ for gross cubic-foot volume to a utilized top

Cull and breakage in trees without, and in trees with, cull indicators in old-growth redwood--by 10-inch d.b.h. classes

D.b.h. class, inches	Trees with no indicators		Trees with indicators					
			Cull associated with--					
	Cull	Breakage	Bole wound (1)	Goose-pen (2)	Broken top (3)	Bole wound + broken top (1 + 3)	Goosepen + broken top (2 + 3)	Breakage
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
21-30	4	0	7	9	7	18	18	0
31-40	3	1	8	12	7	18	21	0
41-50	2	1	8	15	7	19	24	1
51-60	2	2	9	19	7	19	27	2
61-70	1	2	9	23	8	20	31	2
71-80	1	3	10	27	8	21	35	2
81-90	1	4	11	31	8	22	39	2
91-100	1	4	12	35	9	24	44	2
101-110	0	5	14	39	9	26	49	2
111-120	0	6	16	44	10	29	55	2
121-130	0	7	19	49	11	32	62	2
131-140	0	8	22	55	13	36	69	2
141-150	0	8	26	62	15	41	78	2
151-160	0	8	30	70	17	47	88	2

1/ Based on the average cull associated with specific cull indicators.

Table 9.- Indicator factors[1/] for gross cubic-foot volume to a 4-inch top

Cull and breakage in trees without, and in trees with, cull indicators in old-growth redwood--by 10-inch d.b.h. classes

D.b.h. class, inches	Trees with no indicators		Trees with indicators					
			Cull associated with--					
	Cull	Breakage	Bole wound (1)	Goose-pen (2)	Broken top (3)	Bole wound + broken top (1 + 3)	Goosepen + broken top (2 + 3	Breakage
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
21-30	3	2	7	8	19	29	29	2
31-40	3	5	7	10	19	29	31	4
41-50	3	7	7	12	19	30	33	5
51-60	3	8	7	15	20	30	36	6
61-70	3	9	7	18	20	31	39	6
71-80	3	10	8	21	21	32	43	5
81-90	3	11	9	24	22	34	47	5
91-100	3	11	10	27	23	37	51	4
101-110	3	12	12	30	25	40	56	4
111-120	3	12	16	34	27	44	63	4
121-130	3	12	20	39	30	50	70	3
131-140	3	12	24	44	34	56	78	3
141-150	3	12	29	49	38	62	88	2
151-160	3	12	35	55	43	69	98	2

1/ Based on the average cull associated with specific cull indicators.

Bases of Data

Each study area for old-growth redwood was located in a separate logging operation where old growth was being logged in 1950. A total of 495 trees, having a gross volume of nearly 5 million board feet, were used. In Humboldt and Del Norte Counties there were 240 trees on 12 areas, and in Sonoma and Mendocino Counties, 255 trees on 13 areas. The distribution of the trees by d.b.h. classes is shown in table 10. The number of trees which provided the basis for the cull factors for each indicator or group of indicators is shown in table 11.

Table 10.- Number of trees used as a basis in each d.b.h. class in the southern and northern portions of the redwood region

D.b.h. class, inches	Southern: Sonoma and Mendocino Counties	Northern: Humboldt and Del Norte Counties	Total
	No.	No.	No.
21-30	6	0	6
31-40	45	7	52
41-50	58	33	91
51-60	50	33	83
61-70	40	55	95
71-80	33	26	59
81-90	14	23	37
91-100	5	17	22
101-120	3	29	32
121-140	0	9	9
141-160	0	5	5
161-180	0	3	3
181-200	1	0	1
Totals	255	240	495

Trees with two or more indicators, in which cull associated with indicators on the lower bole could be separated from cull associated with indicators on the upper bole, occur two or more times in Table 11. For instance, a tree with a goosepen and a broken top in which cull associations could be separated (no overlapping of cull) was counted in all data which include either goosepen or broken top. If the cull associated with each type of indicator could not have been separated, the tree would occur in the data only once, in the line "Goosepen + broken top." All trees without recognized indicators occur but once in the data, in the line entitled "Trees with no indicators."

Table 11.- Number of trees and study areas which provided indicators for each group of indicator factors

Indicator	Number of trees	Number of areas
Trees with no indicators	187	25
Bole wound	144	25
Goosepen	83	25
Broken top	108	25
Bole wound + broken top	304	25
Goosepen + broken top	207	25

After felling and bucking had been completed, each tree was measured and diagrammed, indicating the utilized top and all breaks. The dimensions of rot, shake, rift crack, fire scars, goosepens, and other defects were measured and diagrammed. The utilized top was taken as actually cut, except in the few trees which were so defective that no logs were cut. For these trees the average utilized top given in table 13 was used to calculate gross volume. Each tree was scaled in both board feet and cubic feet in 20.5-foot log lengths to the top as cut, to a 12-inch top, and in cubic feet between a 12-inch and a 4-inch top. Top sections less than one full saw log were scaled as shorter logs. Any log scaling less than 50 percent net was culled. Broken sections from which a merchantable log 8 feet long or longer could be taken were not classified as loss due to breakage. The broken or shattered ends that would normally be bucked off to make the log merchantable were deducted as breakage. Broken sections that were cull because of rot were deducted as rotten cull rather than breakage.

CULL IN YOUNG GROWTH

A small-scale study was made of cull in young redwood trees, by the writers, in June 1951, on logging operations in Mendocino County. Detailed data were taken on 55 young trees (Table 12) at two locations, in which the sample trees were distributed from creek bottom sites to hillside and ridge-top sites.

The board-foot cull to a 10-inch top was 10 percent of the gross scale, and the cubic-foot cull to a 4-inch top was 4 percent. Breakage in felling was negligible.

Table 12.- Summarized analysis of cull in 55 young-growth redwood trees in Mendocino County 1/

D.b.h. class, inches	Percentage of gross bd.-ft. volume to a 10-inch top that is cull from			Percentage of gross cubic-foot volume to a 4-inch top that is cull from			Tree basis
	Rot	Shake and burning	All causes	Rot	Burning	All causes	Number
11-20	0	0	0	0.2	0	0.2	8
21-30	5.4	0.4	5.8	1.9	0.1	2.0	31
31 and over	14.1	2.5	16.6	5.7	0.9	6.6	16
All	9.0	1.3	10.3	3.4	0.4	3.8	55

1/ The cull percentages are applicable to the following volume tables: Hasel, A. A. Board-foot and cubic-foot volume tables for second-growth redwood. California Forest and Range Experiment Station, Research Note No. 66. 1950.

SUPPLEMENTARY TREE-MEASUREMENT DATA

The following figures and tables present information that may be useful for cruising, scaling, and computing volume and growth of redwood timber.

Age and size of redwood trees

Age counts, recorded to the nearest 50 years, were made on stumps of all trees measured for cull in which fire or rot did not destroy the center. These data are shown in Figure 6, which indicates the relationship of tree d.b.h. to age for old-growth redwood currently being logged. In general the trees in the northern counties were larger than trees of the same age in the southern counties. This probably reflects better growing conditions in the north. Nevertheless, a wide range in d.b.h. was found to occur among trees of the same age in these stands. This means that the size of a tree does not depend alone upon its age. Other factors such as site (soil fertility and climate) and competition within the stand (stand density) also have an important influence on tree growth. Seventy-five percent of the sample trees ranged in age from 200 to 700 years (Fig. 6). The number of trees 1,000 or more years old was small. Only two trees were 1,500 or more years old.

Under conditions in which the stands in the southern counties developed, it required an average of 565 years to grow a 60-inch redwood. The fastest-growing trees took about 250 years to attain 60 inches, but the slowest ones required nearly 1,200 years. In Humboldt and Del Norte Counties growth was somewhat faster. The average age of 60-inch trees was 490 years--200 years for the youngest and 950 years for the oldest.

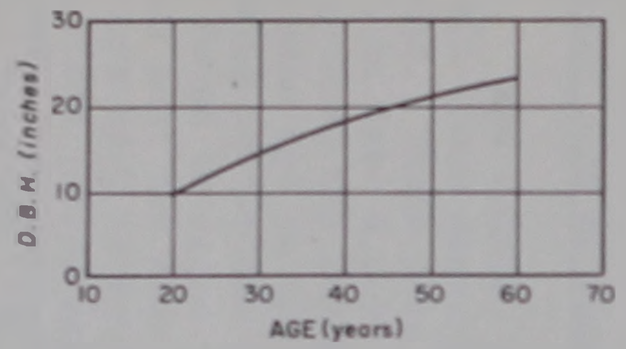
Figure 6 also shows the average relationship of d.b.h. to age of tree in young-growth stands. These data indicate the average growth rate that may be expected in unthinned young growth.

Top utilization

The proportion of the tree used for sawlogs generally depends upon the merchantability of the material in the top. Rot, excessively large or numerous limbs, and breakage may render top material unusable for lumber. Table 13 shows the average utilized top diameter found on a large number of old-growth redwood operations. The utilized top diameter varies with tree size; for old-growth redwood, it was found to range between 45 and 60 percent of d.b.h. In almost one-half of the trees measured the utilized top was at the first break.

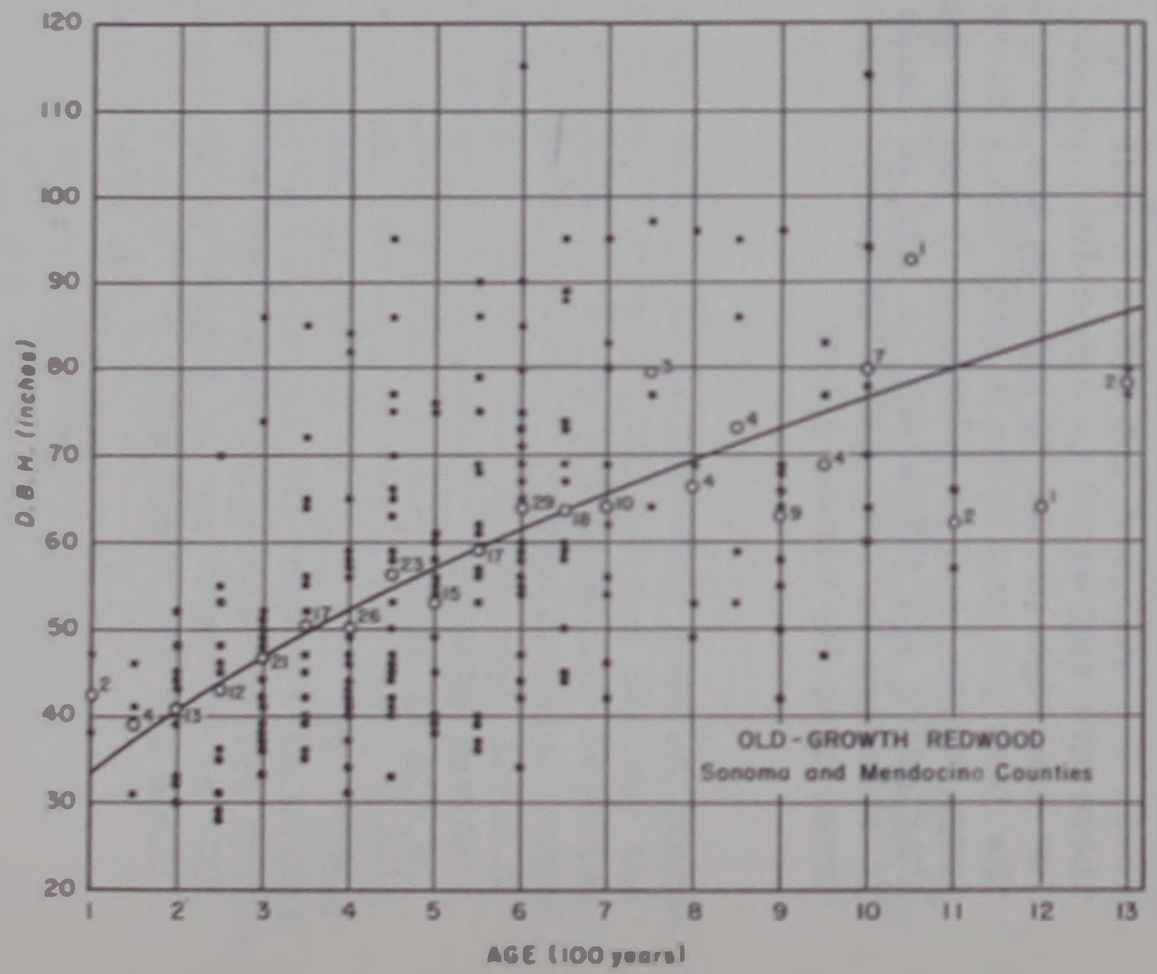
An analysis was made of the sound volume remaining in unutilized tops. Table 14 shows the average gross and sound cubic-foot volume between the utilized top and a 4-inch top, by 10-inch d.b.h. classes. As these are expressed in cubic-foot volume, no deductions have been made for breakage occurring outside the decayed portion. Top material above the last cut may contain many small knots or be rough with scattered large knots, and in addition it may be badly broken. Breakage and shattering are prevalent in tops of large trees where rot is extensive. If breakage is included with decay, little usable material is left in trees over 90 inches d.b.h.

Fig. 6 - Relationship of d.b.h. to age of coastal redwood



YOUNG-GROWTH REDWOOD
SITE I

Source: Bruce, Donald. 1923
Preliminary Yield Tables for
Second-growth Redwood.
Univ. Calif. Press, Berkeley



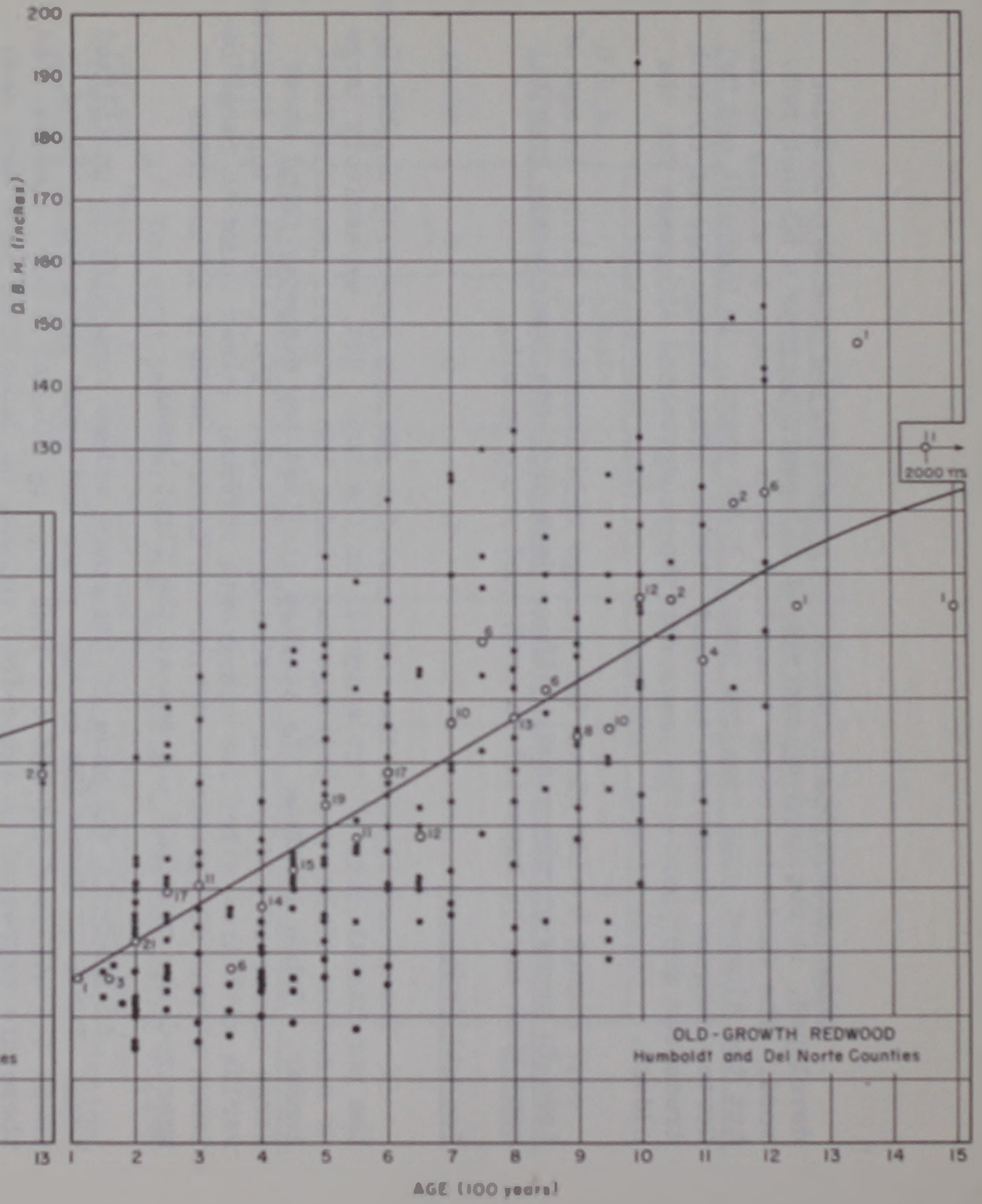


Table 13.- Average 20-foot d.o.b. [1] for measured d.b.h., and average utilized top diameter, inside bark, of old-growth redwood--based on top utilization in industrial logging practice 1948 to 1950 inclusive

D.b.h. class [2]	Average 20-ft. d.o.b. (curved)	Average utilized top [3] d.i.b. (curved)	D.b.h. class	Average 20-ft. d.o.b. (curved)	Average utilized top d.i.b. (curved)
Inches			Inches		
20	16	12	92	74	42
22	18	13	94	74	42
24	18	13	96	76	43
26	20	14	98	78	44
28	22	15	100	80	46
30	24	16	102	80	46
32	26	18	104	82	47
34	28	19	106	84	48
36	28	19	108	86	50
38	30	20	110	86	50
40	32	20	112	88	51
42	34	21	114	90	53
44	36	22	116	92	54
46	38	23	118	92	54
48	40	24	120	94	56
50	40	24	122	96	57
52	42	25	124	98	59
54	44	26	126	100	60
56	46	27	128	100	60
58	48	29	130	102	62
60	48	29	132	104	64
62	50	30	134	104	64
64	52	31	136	106	66
66	54	32	138	108	68
68	56	33	140	110	69
70	56	33	142	112	71
72	58	34	144	112	71
74	60	35	146	114	73
76	62	36	148	116	75
78	62	36	150	118	77
80	64	37	152	118	77
82	66	38	154	120	79
84	68	39	156	122	81
86	68	39	158	124	83
88	70	40	160	124	83
90	72	41	162	126	85

1/ Diameter outside bark 20 ft. above ground line on uphill side.
2/ Basis: 1,159 trees measured throughout the redwood region for cull studies, for volume table studies, and on survey sample plots, applies only to d.b.h.-20-ft. d.o.b. relationship.
3/ Basis: 623 trees measured in 38 localities, applies only to d.b.h.-utilized top relationship.

Table 14.- Average cubic-foot volume between the utilized top and a 4-inch top d.i.b. in old-growth redwood-- by 10-inch d.b.h. classes

D.b.h. class, inches	Gross volume	Sound 1/ volume	Cull
	Cubic feet	Cubic feet	Percent
21-30	25	25	0
31-40	55	50	9
41-50	95	80	16
51-60	165	130	21
61-70	250	185	26
71-80	350	240	31
81-90	470	285	39
91-100	625	330	47
101-110	870	375	57
111-120	1,190	415	65
121-130	1,530	455	70
131-140	1,920	495	74
141-150	2,430	530	78
151-160	3,010	565	81
161-170	3,570	605	83
171-180	4,085	640	84

1/ Sound volume refers to freedom from decay--no deduction has been made for breakage that is not associated with decay.

D.b.h. and 20-ft. d.o.b. relationships

The cull factors in tables 1 to 6 are given for d.b.h. classes. In order to apply these factors either to cruises or to volume tables[4/] based on the diameter 20 feet above the ground (20 ft. d.o.b.), it is necessary to convert 20-ft. d.o.b. to d.b.h., or d.b.h. to 20-ft. d.o.b. For convenience in making either of these conversions, table 13 gives the average 20-ft. d.o.b. when the d.b.h. is measured, and table 15 gives the average d.b.h. when the 20-ft. d.o.b. is measured. Although the values in these tables are similar in some instances, the two tables are basically different. In table 13, the 20-ft. d.o.b. is the average value found for the trees in each 2-inch d.b.h. class. In table 15, on the other hand, the d.b.h. is the average value for the trees in each 2-inch 20-ft. d.o.b. class. These tables should not be read in reverse.

Bark thickness

In making growth studies, it is desirable to convert measurements of diameter outside bark to diameter inside bark. The data given in table 16 facilitates this conversion for redwood. The thickness of the bark on redwood varies considerably with age, diameter, and fire history. Even for a single tree, there may be several inches difference in thickness from one side to the other. Burning of the bark near the base of the tree often results in the bark being thinner on one side than on the opposite side. Also for this reason the bark at the top of the first log is frequently thicker than at stump height. Table 16 gives the average (curved) double bark thickness at breast height for both young-growth and old-growth redwood.

Extension of log rules

Values for the Scribner Decimal C and for the International 1/4-inch log rules are generally not available for diameters larger than 120 inches and 60 inches respectively. This is a hindrance to the use of either of these rules for scaling old-growth redwood. The values for each of these rules have been extended by formula to the large diameters required for old-growth redwood. Table 17 gives the extension of the International 1/4-inch log rule for 20-foot logs from 61 to 150 inches in diameter. Table 18 gives the extension of the Scribner Decimal C log rule for diameters 121 to 150 inches for both 16-foot and 20-foot logs.

For those who wish to compute cubic volume of logs, table 19 gives the solid cubic volume of 20-foot logs with a half-foot trimming allowance. The cubic volume of redwood trees can easily be computed by applying the volumes given in this table to Hallin's taper tables[4/] for old-growth redwood.

4/ See footnote 3, page 8.

Table 15.- Average d.b.h. for measured 20-foot d.o.b., for old-growth redwood

20-ft. d.o.b. 1/ class	Average d.b.h. class (curved)	20-ft. d.o.b. class	Average d.b.h. class (curved)
------ Inches -------		------Inches -----	
16	22	82	100
18	24	84	102
20	26	86	104
22	28	88	108
24	30	90	110
26	34	92	112
28	36	94	114
30	38	96	116
32	40	98	120
34	42	100	122
36	46	102	124
38	48	104	126
40	50	106	128
42	52	108	132
44	54	110	134
46	58	112	136
48	60	114	138
50	62	116	140
52	64	118	142
54	66	120	146
56	70	122	148
58	72	124	150
60	74	126	152
62	76	128	156
64	78	130	158
66	82	132	160
68	84	134	162
70	86	136	164
72	88	138	168
74	90	140	170
76	92	142	172
78	96	144	174
80	98	146	176

Basis: 1,159 trees measured throughout the redwood region on cull factors, on volume table studies, on logging waste plots, and on survey sample plots.

1/ Diameter outside bark 20 feet above upper ground line.

Table 16.- Average double bark thickness at breast height of old-growth and of young-growth redwood

D.b.h. o.b.	Double bark thickness		D.b.h. o.b.	Double bark thickness	D.b.h. o.b.	Double bark thickness
	Old growth	Young growth		Old growth		Old growth
	Inches			Inches		Inches
6	-	1.0	72	9.5	138	11.9
8	-	1.3	74	9.7	140	11.9
10	-	1.6	76	9.8	142	12.0
12	-	1.9	78	9.9	144	12.0
14	-	2.2	80	10.0	146	12.0
16	-	2.5	82	10.2	148	12.0
18	-	2.8	84	10.3	150	12.0
20	4.7	3.1	86	10.4		
22	4.9	3.4	88	10.5		
24	5.2	3.8	90	10.6		
26	5.5	4.2	92	10.7		
28	5.7	4.5	94	10.8		
30	6.0	4.8	96	10.9		
32	6.2	5.1	98	11.0		
34	6.4	5.4	100	11.0		
36	6.7	5.7	102	11.1		
38	6.9	5.9	104	11.2		
40	7.0	6.1	106	11.3		
42	7.3	6.4	108	11.3		
44	7.4	6.5	110	11.4		
46	7.6	6.7	112	11.4		
48	7.8	6.9	114	11.5		
50	8.0	7.0	116	11.5		
52	8.1	7.2	118	11.6		
54	8.3	7.4	120	11.6		
56	8.5	7.6	122	11.7		
58	8.6	7.8	124	11.7		
60	8.7	8.0	126	11.7		
62	8.9	-	128	11.8		
64	9.0	-	130	11.8		
66	9.1	-	132	11.8		
68	9.3	-	134	11.8		
70	9.4	-	136	11.9		

Basis: 785 old-growth trees and 149 young-growth trees measured throughout the redwood region.

Table 17.- International 1/4-inch log rule for 20-foot logs

For diameters 61 to 150 inches, inside bark, at small end of log[1/]

D.i.b., inches	Volume	D.i.b., inches	Volume	D.i.b., inches	Volume
	Bd.ft.		Bd.ft.		Bd.ft.
61	3,630	91	8,130	121	14,430
62	3,750	92	8,310	122	14,670
63	3,870	93	8,495	123	14,910
64	4,000	94	8,680	124	15,155
65	4,125	95	8,865	125	15,405
66	4,255	96	9,055	126	15,650
67	4,385	97	9,245	127	15,905
68	4,520	98	9,440	128	16,155
69	4,655	99	9,635	129	16,410
70	4,790	100	9,830	130	16,665
71	4,930	101	10,030	131	16,925
72	5,070	102	10,230	132	17,185
73	5,215	103	10,435	133	17,450
74	5,360	104	10,640	134	17,715
75	5,505	105	10,845	135	17,980
76	5,655	106	11,055	136	18,250
77	5,805	107	11,265	137	18,520
78	5,960	108	11,480	138	18,790
79	6,115	109	11,695	139	19,065
80	6,270	110	11,910	140	19,340
81	6,430	111	12,130	141	19,620
82	6,590	112	12,350	142	19,900
83	6,755	113	12,570	143	20,185
84	6,920	114	12,795	144	20,470
85	7,085	115	13,025	145	20,755
86	7,255	116	13,250	146	21,045
87	7,425	117	13,485	147	21,335
88	7,600	118	13,715	148	21,625
89	7,775	119	13,950	149	21,920
90	7,950	120	14,185	150	22,215

1/ Volume, bd.ft. of 20-ft. logs = $(1.1D^2 - 1.35D - 1.9) \times 0.905$. Derived from the published formula: $V = (0.22D^2 - 0.71D) \times 0.905$ for 4-ft. section; assumed taper: 1/2 inch per 4-ft. of length.

Values for logs smaller than 60 inches may be found in the following references: Forest mensuration text books; the California Pine Region Forest Handbook; Converting Factors and Tables of Equivalents Used in Forestry, U.S.D.A. Misc. Pub. No. 225; and National Forest Scaling Handbook.

Table 18.- Scribner Decimal C Log Rule

16-foot and 20-foot logs, for diameters 121 to 150 inches, inside bark, at small end of log1/

Diameter, inches	Volume when log length is--	
	16 ft.	20 ft.
	---- Board feet in tens ----	
121	1,132	1,415
122	1,151	1,439
123	1,170	1,463
124	1,189	1,487
125	1,209	1,511
126	1,229	1,536
127	1,248	1,560
128	1,268	1,585
129	1,288	1,610
130	1,309	1,636
131	1,329	1,661
132	1,350	1,687
133	1,370	1,713
134	1,391	1,739
135	1,412	1,765
136	1,434	1,792
137	1,455	1,819
138	1,476	1,846
139	1,498	1,873
140	1,520	1,900
141	1,542	1,927
142	1,564	1,955
143	1,586	1,983
144	1,609	2,011
145	1,632	2,039
146	1,654	2,068
147	1,677	2,097
148	1,700	2,125
149	1,724	2,155
150	1,747	2,184

1/ Volume of 16-ft. logs = $(0.79D^2-2D-4) \div 10$
Volume of 20-ft. logs = $(0.79D^2-2D-4)\ (1.25) \div 10$.

Values for logs 90 to 120 inches in diameter may be found in the National Forest Scaling Handbook. Values for logs less than 90 inches may be found in references given at bottom of table 17.

Table 19.- Cubic contents of 20.5-foot logs

(Based on the average of the inside bark diameters of the two ends)

Average diameter, inches	Volume Cu.ft.	Average diameter, inches	Volume Cu.ft.	Average diameter, inches	Volume Cu.ft.	Average diameter, inches	Volume Cu.ft.
12	16.1	48	258	84	789	120	1610
13	18.9	49	268	85	808	121	1637
14	21.9	50	280	86	827	122	1664
15	25.2	51	291	87	846	123	1692
16	28.6	52	302	88	866	124	1719
17	32.3	53	314	89	886	125	1747
18	36.2	54	326	90	906	126	1775
19	40.4	55	338	91	926	127	1803
20	44.7	56	351	92	946	128	1832
21	49.3	57	363	93	967	129	1861
22	54.1	58	376	94	988	130	1890
23	59.1	59	389	95	1009		
24	64.4	60	402	96	1030		
25	69.9	61	416	97	1052		
26	75.6	62	430	98	1074		
27	81.5	63	444	99	1096		
28	87.7	64	458	100	1118		
29	94.0	65	472	101	1141		
30	101	66	487	102	1163		
31	107	67	502	103	1186		
32	114	68	517	104	1209		
33	122	69	532	105	1233		
34	129	70	548	106	1256		
35	137	71	564	107	1280		
36	145	72	580	108	1304		
37	153	73	596	109	1328		
38	161	74	612	110	1353		
39	170	75	629	111	1378		
40	179	76	646	112	1402		
41	188	77	663	113	1428		
42	197	78	680	114	1453		
43	207	79	698	115	1479		
44	216	80	716	116	1504		
45	226	81	734	117	1531		
46	237	82	752	118	1557		
47	247	83	770	119	1583		